REMARKS

Claims 7, 15 and 19 have been canceled and the subject matter thereof has been combined with claims 1, 14 and 17 respectively. The dependent claims have been amended, as appropriate so they do not depend on a canceled claim. Claims 20, 25, and 28 have been amended so they are directed to a memory, to provide consistency between these dependent claims and the claim upon which they depend. The amendments to claims 20, 25, and 28 obviate the rejection thereof under 35 USC 112, ¶2.

Applicants again request reconsideration of the withdrawal of claims 14 and 16 from further consideration under 37 CFR 1.142(b). Applicants cannot agree that the invention of claims 14 and 16 is independent and distinct from the invention of the remaining claims. Independent claims 1 and 17 are respectively directed to a method of processing a workpiece and a memory storing a computer program for controlling a computer for controlling processing of a workpiece in a vacuum plasma processing chamber. Claim 14 is directed to a vacuum plasma processor with a controller that performs the method of claim 1 or which typically includes a memory as defined in claim 17. The operations of the controller of claim 14 are the same as the method steps of claim 1 and the steps which the memory of claim 17 causes a computer to perform. As such, applicants fail to see how the invention of claim 14 is independent and distinct from the invention of claims 1 and 17. As pointed out by the Examiner on page 7 of the office action, using a computer i.e., controller, to automate a known process does not impart unobviousness to an invention. Consequently, the subject matter of claims 14 and 16 is not an invention that is independent and distinct from the invention of the method claim 1 and memory of claim 17. Further, the Examiner has not required restriction between claim 24 and the method claim1 and the memory of claim 17, despite the fact that claim 24 depends on claim 14. Since claim 24 includes all the limitations of claim 14, the Examiner has, in fact, considered claim 14. This is further evidence of the impropriety of the restriction requirement. Consequently, consideration of all pending claims is in order.

The rejection of claims of 1-13 and 17-29 under 35 USC 112, ¶1, as failing to comply with the written description requirement is traversed. The Examiner's position that the specification, as originally filed, fails to support the limitation of gradually changing the amount

of AC power applied to the plasma during processing of the workpiece "while the power is in a steady state condition subsequent to power start-up and prior to the beginning of power shut down" is erroneous. Figures 2-4 of the application as filed clearly indicate the amount of AC power applied to the plasma gradually changes during processing of the workpiece while the power is in a steady state condition subsequent to power start up and prior to the beginning of power shut down. This is because the waveforms of these figures indicate that prior and subsequent to the gradual changes, the power is in a constant, i.e., steady state, condition. In this regard, the attention of the Examiner is directed to paragraph 7 of the enclosed Declaration of Tuquiang Ni.

It is also implicit from the requirements of claims 9-11 (for example) as filed and the corresponding portions of the specification that the power is in a steady state condition subsequent to power start-up and prior to the beginning of power shut down. In particular, a trench wall including a rounded corner, particularly a rounded corner at an intersection of a wall and base of a trench, is formed while the power is in a steady state condition subsequent to power start-up and prior to the beginning of power shut down. Based on the foregoing, withdrawal of the rejection of based on 35 USC 112, ¶1 is in order.

The claims extant in the application are patentable over the combination of Chen et al., US Patent 5,807,789, in view of Tsuchiya, US Patent 5,716,534 and further in view of Howald, WO 00-58992. The attention of the Examiner is directed to paragraphs 4-6 of Dr. Ni's enclosed Declaration with regard to this rejection. Firstly, as a minor point, Chen et al. fails to disclose the requirements of claim 4, which says the electrode is responsive to an AC power source that supplies RF bias voltage to an electrode on a holder carrying the workpiece. In addition, such operation is not inherent in Chen et al., as indicated by paragraph 4(b) of Dr. Ni's Declaration because the application of 400 watts to the electrode holding the substrate would cause the Chen et al. mask to be vaporized.

More importantly, Dr. Ni has testified in paragraph 4(c) of his Declaration that the gradual changes in the sidewall angles of the Chen et al. method are not obtained by changing the RF power. Dr. Ni explains that the sidewall angles change because of etch by-products that accumulate (1) inside the etch chamber, (2) on the sidewall, and (3) in the bottom of the trench. As Dr. Ni testified, Chen et al. reduces the etch rate and therefore the deposition rate of the by-

products on the sidewall by reducing the plasma density as a result of a reduction of the RF power supplied to the plasma. In other words, Chen et al. reduces the RF power applied to the plasma at the top of the chamber from step 1 to step 2 to step 3 to obtain a reduced amount of by-product deposition on the vertical wall of the chamber. Dr. Ni has testified that Chen et al. does not obtain a gradual transition the shape of the material in response to the power changes from 800 watts to 700 watts to 650 watts which occur only at the beginning of these three steps. He has also testified that Chen et al. does not provide a gradual power change that occurs during a gradual transition in the shape of the trench formed in substrate 30.

Based on Dr. Ni's testimony and analysis of the Chen et al. device, Chen et al. fails to recognize that gradual changes in the power applied to the plasma would produce the results which Chen et al. were attempting to obtain. It would appear that greater control over the deposition can be obtained by gradually changing the power applied to the plasma than can be obtained by controlling the etch by-products deposited in the workpiece by the mechanism Chen et al. employs and described by Dr. Ni.

Dr. Ni cannot agree with comments made in the office action concerning the Tsuchiya et al. reference. In this regard, Dr. Ni, in paragraph 5(a) of his Declaration says he cannot agree with the statement bridging pages 5 and 6 of the August 19, 2003 office action that:

> Tsuchiya et al. discloses a process whereby during an etching process the RF power is either in a step-wise manner or gradually changed subsequent to power start up and prior to the beginning of power shut down in order to provide, for example, a hole or sidewall with tapered sides (see col. 12 - 13 – line 37).

Dr. Ni also does not agree with the Examiner's statements on pages 7 and 8 of the August 19, 2003 office action that:

> . . . in Tsuchiya et al. that during the time the power is gradually changed, etching gas and the wafer are still in the chamber, plasma continues to be generated, and therefore etching still takes place during the time the power is gradually changed (see col. 12-line 58 to col. 13-line 27). Additionally, note that the Tsuchiya et al. discloses that the method can be used in order to tailor the taper angle of an etched hole . . .

Dr. Ni's testimony indicates that the Examiner's foregoing statements are contrary to statements appearing in columns 12 and 13 of the Tsuchiya et al. reference. Dr. Ni has testified

that the embodiment apparently referred to in the Chen et al. patent is associated with Figures 30 and 31 and not the embodiment of Figures 32 and 33. In paragraph 5(c) of his Declaration, Dr. Ni has testified that the gradual changes indicated by the waveforms of Figures 32 and 33 of Chen et al. would not result in a hole having optimized walls. Dr. Ni has testified that optimized walls of holes have an angle that is as close as possible to 90° with respect to the top face of a semiconductor wafer. The bottom of an optimized hole is as close as possible at right angles to the sidewall of the holes. This is in contrast to the structure of trenches which desirably have round intersections between the trench wall and the trench bottom face and slope angles of approximately 80° with respect to the top face of the workpiece. Dr. Ni has testified that if a hole were formed by gradually changing the power such a hole would not have the optimal walls at right angles to the workpiece. As a consequence of this, Dr. Ni has concluded that the words "in this embodiment" in the Tsuchiya et al. reference refer to the embodiment of Figures 30 and 31, wherein power is suddenly applied to and removed from the electrode and that the words "in this embodiment" are not applicable to the gradual transitions.

As a result of the foregoing, Dr. Ni has testified in paragraph 6 of his Declaration that Tsuchiya et al. does not disclose (1) changing the amount of AC power supplied during processing of a workpiece while the power is in a steady state condition subsequent to power start up and prior to the beginning of power shut down or (2) a gradual transition in the shape of material being processed in response to the gradual power change, wherein the gradual power change occurs during the gradual transition in the shape of the material.

Based on the foregoing, neither Chen et al. nor Tsuchiya et al. discloses the requirement of claims 1, 14 or 17 of gradually changing on a pre-program basis, the amount of AC power supplied to the plasma during processing of the workpiece while the power applied to the plasma is in a steady state condition subsequent to power start up and prior to the beginning of power shut down and a gradual transition in the shape of the workpiece being processed occurring in response to the gradual power change, wherein the gradual power change occurs during the gradual transition in the shape of the material.

Applicants also note that the entire purpose of the Tsuchiya et al. device, in the embodiments of Figures 30-33, is to prevent charge damage to the workpiece, by essentially staggering the start and stop times of the power applied to the top and bottom electrodes. The

Tsuchiya et al. reference has nothing to do with forming corners or sloping walls of trenches as claims 8-11 and 20-22 require. Consequently, one of ordinary skill in the art would not have been motivated to combine Tsuchiya et al. with Chen.

The Examiner admits that Chen et al., in addition to failing to disclose changing RF power substantially, continuously and gradually, fails to disclose a gradual pre-programmed power change while no change occurs in pressure, as claims 2, 16 and 18 require. Applicants note that the Examiner has not properly considered the pressure change limitation in the office action. Further, modification of Chen et al. to include the foregoing limitations of claim 2, 16 and 18 flies in the face of Chen et al. which indicates that pressure is changed at the beginning at each of the steps. During step 1, the chamber pressure is 50 millitorr (mT). At the beginning of the second step, process pressure is changed by being increased about 60 percent from 50 mT to 80 mT. At the beginning of the third step, the chamber pressure is increased to about 100 mT. The changes in pressure are important to control the deposition of by-products on the Chen et al. workpiece, as inferred from paragraph 4(c) of Dr. Ni's Declaration. Hence, one of ordinary skill in the art would not have modified Chen at al. to maintain chamber pressure constant.

The Examiner's proposal to modify Chen et al. to apply etching power to the bottom electrode, as a result of the Howald et al. disclosure is incorrect. As pointed out in paragraph 4(b) of Dr. Ni's Declaration, one of ordinary skill in the art would not have modified Chen et al. to apply etching power to the bottom electrode because the application of power to the bottom electrode would have a deleterious effect on the workpiece processing.

In view of the foregoing amendments and remarks, favorable reconsideration and allowance are requested and deemed in order.

To the extent necessary, a petition for an extension of time under 37 C.F.R. 1.136 is hereby made. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account 07-1337 and please credit any excess fees to such deposit account.

Respectfully submitted,

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Docket No.: 2328-053

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	:
NI, TUQUIANG	:
U.S. Patent Application No. 09/821,753	: Group Art Unit: 1763
Filed: March 30, 2001	: Examiner: LUZ L ALEJANDRO

For: PLASMA PROCESSING METHOD AND APPARATUS WITH CONTROL OF PLASMA EXCITATION POWER

Commissioner For Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF TUQUIANG NI

1. I am one of the applicants of the referenced application. I have a Ph.D. in Chemistry from the University of Texas, Dallas, 1990. I earned this degree after obtaining undergraduate degrees in China.

2. I am currently employed at Lam Research Corporation as a Principle Technologist. I have been employed by Lam since 1995 and perform research on plasma processing methods and equipment, in particular for etching poly-silicon and dielectric materials of integrated circuits. I am a member of the American Vacuum Society. I regularly attend seminars relating to plasma processing of workpieces, such as semiconductor wafers used to make integrated circuits. The seminars are held by various organizations. I also regularly attend meetings of the American Vacuum Society and attend the technical symposia at these meetings. I read the reports from the seminars and the meetings to remain current in the field of plasma processing.

3. I am an inventor of fifteen U.S. patents, including U.S. patent 6,042,687 entitled "Method and Apparatus for Improving Etch and Deposition Uniformity in Plasma Semiconductor Processing"

and U.S. patent 6,013,155 entitled "Gas Injection System for Plasma Processing." Both of these patents relate to plasma processing of workpieces, such as semi-conductor wafers used to make integrated circuits and flat panel displays of the type used in some computers and television receivers. Other U.S. patents related to plasma processing that I have co-authored are: 6,052,176; 6,067,729; 6,203,657; 6,229,264; 6,230,651; 6,257,168; 6,388,383; 6,451,158; 6,461,974; 6,465,195; 6,514,378; and 6,416,355. Because of my education and work experience, I am knowledgeable of the apparatus employed in vacuum plasma processors for depositing materials on and etching materials from semi-conductor wafers and other similar workpieces. As a result of my experience and knowledge in the field of plasma processing methods and equipment, I am qualified to discuss the intricacies of Chen et al. U.S. patent 5,807,789 and Tsuchiya et al. U.S. patent 5,716,534.

4(a). I have carefully studied Chen et al. US patent 5,807,789. The Chen et al. patent discloses a method of forming shallow trench isolation (STI) regions in substrate 30. Substrate 30 carries nitride and oxide layers 32 and 34, respectively, and mask 35 having openings which permit a plasma to attack and etch layers 32 and 34. During a preliminary step, a chamber including substrate 30 that carriers layers 32, 34 and 35 is maintained at a constant pressure of 50 millitor and 400 watts of power is applied for an unspecified time to an electrode that excites gas in the chamber to a plasma in the chamber. During the preliminary step, nitride layer 32 and oxide layer 34 are etched according to the pattern of mask layer 35, as illustrated in Figure 5. After layers 32 and 34 have been etched, the trenches in substrate 30 are formed using oxide layer 32 and nitrite layer 34 as a mask for the trenches. The trenches are formed by a three step process. During the first step, 800 watts of power are applied to the electrode for eight seconds and the pressure in the chamber is about 50 millitor. The patent says the first step enables round top corners to be achieved. In a second eight second step, 700 watts of power are applied to the electrode and the pressure in the chamber is increased to 80 millitor. In the third 46 second step, the power applied to the electrode is reduced further to 650 watts and the chamber pressure is increased to 100 millitor.

4(b). Based on my experience and as would be recognized by those with whom I have worked, Chen et al. was not applying power to the plasma by an electrode that was carrying substrate 30; such an electrode is frequently referred to as a bottom electrode. Due to my experience 400 watts of

power could not have been applied to an electrode that was carrying substrate 30 in the Chen et al. chamber because such a large power applied to the electrode holding the substrate would have caused the mask to be vaporized. Hence, I conclude that the power must have been applied to the top electrode, i.e. the electrode opposite from the electrode holding substrate 30.

4(c). In the Chen et al. method, the gradual changes in the sidewall angles at the top, bottom and along the length of the sidewall between the top and bottom of the trench are not obtained by changing the RF power. In Chen et al., the RF power is fixed for each of these steps. The sidewall angle is changed because etch by-products that accumulate inside the etch chamber also accumulate in the sidewall and bottom of the trench. It is the general practice of operators of etch systems to set a high chamber pressure to choke the exhaust of the vacuum chamber. The chamber automatically responds to the high pressure by closing down a valve leading to a vacuum pump connected to the chamber. The by-products thus deposit on the sidewall of the trench. Increased deposition on the sidewall as a result of the by-products results in the wall of the trench deviating substantially from a 90° angle relative to the top face of the workpiece comprising substrate 30. To provide more time for the by-products to deposit on the sidewall during the second and third steps, the etch rate is reduced by reducing power applied to the plasma only at the beginning of each of the second and third steps. Chen et al. reduces the etch rate and therefore the deposition rate of the by-products on the sidewall by reducing the RF power the top electrode supplies to the plasma which in turn reduces the density of the plasma that etches the sidewall. Hence, Chen et al. reduces the top electrode RF power from step 1, to step 2, to step 3, to obtain a reduced rate of by-product deposition on the vertical wall of the chamber. Chen et al. does not obtain a gradual transition in the shape of the material in substrate 30 by causing the power to be 800 watts, 700 watts, and 650 watts only at the beginning of each of the three steps. Chen et al. does not have a gradual power change that occurs during a gradual transition in the shape of the trench formed in substrate 30.

5(a). I have carefully reviewed Tsuchiya et al. US patent 5,716,534 and cannot agree with the statement bridging pages 5 and 6 of the August 19, 2003 office action that:

> Tsuchiya et al. discloses a process whereby during an etching process the RF power is either in a step-wise manner or gradually changed subsequent to power start up and prior

> to the beginning of power shut down in order to provide, for example, a hole or sidewall with tapered sides (see col. 12-13 – line 37).

I also cannot agree with the Examiner's statements on pages 7 and 8 of the August 19, 2003 office action that:

> . . . in Tsuchiya et al. that during the time the power is gradually changed, etching gas and the wafer are still in the chamber, plasma continues to be generated, and therefore etching still takes place during the time the power is gradually changed (see col. 12-line 58 to col. 13-line 27). Additionally, note that the Tsuchiya et al. discloses that the method can be used in order to tailor the taper angle of an etched hole . . .

I cannot agree with the Examiner's statement because Tsuchiya et al., (beginning in the sentence bridging columns 12 and 13) states:

> After predetermined etching is performed, plasma generation is ended in accordance with the timing chart shown in Figure 31. More specifically, the RF power to the lower electrode 4 is cut-off first, and after a lapse of 5 to 10 seconds, the RF power to the upper electrode 21 is cut off. In this way, the dissociation count of the plasma is decreased step-wise, so the charge-up damage to the wafer can be minimized. When the RF power to the lower electrode 4 is cut off first, the charges accumulated on the wafer W can be removed . . .
>
> Upon the start and stop of the plasma generation, the RF powers can be adjusted step-wise, i.e., by step-up and step-down manner, as indicated by solid lines in Figures 32 and 33. The RF powers can be adjusted in the slow-up and slow-down manner, as indicated by broken lines in Figures 32 and 33.
>
> In the above embodiment, optimization of the etching rate, the planar uniformity of the etching rate, and the etching selectivity ratio have been described. The taper angle of the sidewall of an etched hole and anisotropy of etching, and the like can be optimized by adjusting parameters similar to those in this embodiment.

5(b). I cannot agree with the Examiner's conclusions regarding the Tsuchiya et al. reference because the embodiment being referred to is apparently the embodiment associated with Figures 30 and 31, and not the embodiment of Figures 32 and 33. The embodiment of Figures 30 and 31 respectively deals with suddenly applying power to upper electrode 21, prior to suddenly applying power to lower electrode 4 of Tsuchiya et al. and suddenly removing power from lower electrode 4 prior to suddenly removing power from upper electrode 2. Tsuchiya et al. indicates

power is applied to and removed from the upper and lower electrodes in this manner so charge-up damage to the wafer can be minimized.

5(c). Figures 32 and 33, together, represent a modification of the timing charts of Figures 30 and 31. In Figures 32 and 33 there are gradual changes in the power supplied to the top and bottom electrodes after etching is performed (see the sentence bridging columns 12 and 13). I do not believe starting and stopping in conjunction with the embodiments of Figures 32 and 33 can cause the taper angle of the sidewall of an etched hole to be optimized. Optimized walls of holes have an angle that is 90° with respect to the top face of a semiconductor wafer. The bottom of an optimized hole is at 90° relative to the sidewall of the hole. Holes are made in this way because they are filled with a metal that forms a contact of an integrated circuit made from the wafer. In contrast, trenches desirably have round intersections between the trench wall and the trench bottom face. In addition, trench walls typically have slope angles of approximately 80° with respect to the top face of the workpiece. Trenches are filled with a dielectric to provide electrical isolation between electrical components formed on the integrated circuit. The dielectric does not properly adhere to the trench unless the trench has sloping walls. Better adhesion between the dielectric and the trench surface is also provided by rounding the intersection between the trench wall and trench bottom. If a hole wall were formed by gradually changing the power applied to the plasma such a hole would not have the optimum walls at right angles to the face workpiece.

5(d). Gradually decreasing the power applied to a hole results in the hole having sloping sidewalls, rather than sidewalls having the optimum 90° relationship with respect to the top face of the substrate. In the extreme, gradually decreasing the power applied to the hole would cause the hole to have a needle shape, i.e., a point at its bottom, which is a very undesirable shape for a hole. Consequently, in my opinion, Tsuchiya et al. does not want a sidewall of a hole to have tapered sides, as alleged on page 6 of the office action. In order to form the sharp, optimized 90° intersection between the hole wall and bottom, it is necessary to rapidly turn off the power applied to the plasma. To obtain such a result and minimize charge, the embodiment of Figure 31, wherein power applied to the plasma by (1) the lower electrode is suddenly changed from on to off and (2) the upper electrode is subsequently suddenly changed from on to off of the upper

electrode, would have to be used and the embodiment of Figures 32 and 33 would not be used. Hence, in my opinion, the words "in this embodiment" in the Chen et al. patent must be interpreted to be in connection with Figures 30 and 31, rather than Figures 32 and 33. This is because the embodiment of Figure 31 enables a hole having the desired characteristics to be formed, and reduces the charge damage to the wafer. In my opinion, the words "in this embodiment" in column 13 must refer to the power applied to the hole in connection with Figure 32 or 33 because I do not see how Figure 32 or 33 can be used to form a hole having an optimized taper angle.

6. Consequently, Tsuchiya et al., in my opinion, does not disclose (1) changing the amount of AC power supplied during processing of a workpiece while the power is in a steady state condition subsequent to power start up and prior to the beginning of power shut down or (2) a gradual transition in the shape of material being processed in response to the gradual power change, wherein the gradual power change occurs during the gradual transition in the shape of the material.

7. I also believe that one of ordinary skill in the art, upon reading the present application and reviewing the drawings, would know that the gradual changes are in the steady state and occur subsequent to start-up and prior to the beginning of shut-off because the gradual power changes 170, 172 and 174 are illustrated and described in connection with Figures 2-4 as being between steady state powers P1 and P2, respectively, prior to time T1 and subsequent to T2 or prior to T3 and subsequent to T4. One of ordinary skill would understand that constant power P1 was applied to the plasma in Figure 2 prior to T1 and power P2 was removed from the plasma subsequent to T2, that constant power P2 was applied to the plasma in Figure 3 prior to T1 and power P1 was removed from the plasma subsequent to T2, that constant power P3 was applied to the plasma in Figure 4 prior to T3 and power P4 was removed from the plasma subsequent to T4.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are

punishable by fine, or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

DATED this 20 day of October, 2003, at Fremont, California.

Tuqiang Ni

Tuqiang Ni

Certificate of Mailing

I hereby certify this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: (Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450)

On October 20, 2003